

**APPENDIX 4-A**

## **Phase II RFI Field Methodology**

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**APPENDIX 4-A**

**PHASE II RCRA FACILITY INVESTIGATION METHODOLOGY**

**EAST HELENA, MONTANA**

Prepared by Hydrometrics, Inc.

Modified by GSI Water Solutions, Inc.

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## 1.0 PHASE II RFI CHARACTERIZATION METHODOLOGY

The Phase II RCRA Facility Investigation (RFI) site characterization activities were conducted in 2010 in accordance with the *Phase II RFI Work Plan* (Hydrometrics, 2010a). Any significant deviations from the work plan are presented in this section. Sampling locations, sampling procedures, quality assurance/quality control (QA/QC) procedures, and analytical requests are also presented in this section, with all data analysis and interpretation presented in the body of the *Phase II RFI Report* of the main report.

### 1.1 PHASE II SURFACE SOIL SAMPLING

As outlined in the work plan, surface soil samples, defined as samples collected within the upper 60 inches (5 ft), were collected in August 2010 at selected locations within and peripheral to the plant site. The Phase II surface soil locations included a subset of sites previously sampled during the Phase I RFI (19 sites), and all Phase II monitoring well (9 sites) and soil boring (20 sites) locations, for a total of 48 sample sites. Phase II RFI surface soil sampling locations are shown in the *Phase II RFI Report*. Additional surface soil samples were collected in 2010 for the baseline ecological risk assessment (BERA); sample rationale, locations, and sampling methodologies are described in the BERA work plan and report (Gradient, 2010a; Gradient, 2010b).

Objectives of the Phase II surface soil sampling program included:

- Provide soil chemistry data from a subset of previously sampled locations to provide data for an expanded list of metals and selenium;
- Provide current information on shallow soil conditions at the site for evaluation of appropriate corrective measures; and
- Provide information for use in the Baseline Ecological and Human Health Risk Assessments.

Based on these objectives, surface soil samples were collected from the 0 to 6-inch, 6 to 30-inch and 30 to 60-inch depth intervals at each of the 48 sampling locations. The 0 to 6-inch and 6 to 30-inch depth intervals correspond in general to those previously sampled during the Phase I RFI, allowing for comparison of the Phase I and Phase II results. The 0 to 6-inch interval samples were also used in the 2010 Baseline Ecological Risk Assessment (BERA), while the 30- to 60-inch samples were collected for possible evaluation of a construction worker scenario in the Human Health Risk Assessment. In addition to the 48 sites sampled under the surface soil sampling program, an additional 31 surface soil samples (0 to 6-inch) were collected by Hydrometrics in support of the 2010 BERA. Results for these samples are reported separately in the BERA report (Gradient, 2010a).

A number of sites identified for surface soil sampling in the *Phase II RFI Work Plan* were eliminated from the program for various reasons. These include:

- Rail Car Staging Area locations RCSA-2, RCSA-5 and RCSA-8: These sites are located west of the plant site and off Trust property. The sites were eliminated from the program with the consent of the regulatory agencies due to delays in obtaining access agreements from the property owner.

- Unpaved Plant Site Area location UPS-SS-5: This site is located next to the former Sample Crushing Mill building which was demolished in 2009. Extensive soil sampling was conducted in this area following demolition of the mill, with samples tested for a full suite of parameters including selenium. Due to the availability of soils data from this area, the site was eliminated from the Phase II RFI program with agency approval.
- Soil Boring RFI2SB-19: This site is located within the footprint of former Thornock Lake process pond, which underwent remediation between 1986 and 1991. The soil boring (and associated surface soil sampling) was eliminated with agency consent due to the presence of overhead power lines and the availability of existing data from the area.
- Thornock Lake site TL-003: Site TL-003 is also located near former Thornock Lake. Surface soil sampling was deemed unnecessary by the agencies since soils were excavated to depths of about 10 feet and replaced with clean fill at that time.
- Acid Plant site SS-28: This site is located near the former Acid Plant, and near Phase II soil boring RFI2SB-18. The site was eliminated from the program with agency consent due to the proximity to SB-18 (and associated soil sampling at SB-18).
- On-Site Rail Corridor site RC-SS-22: This site was eliminated from the program with agency consent due to its proximity to soil boring RFI2SB-8 (and associated soil sampling at SB-8).

All other proposed locations as described in the work plan were sampled in August 2010.

### **1.1.1 Surface Soil Sampling Methodology**

The surface soil sampling methodology was conducted as specified in the project *Quality Assurance Project Plan* (QAPP; Hydrometrics, 2010b) and the project *Field Sampling and Analysis Plan* (FSAP; Hydrometrics, 2010c). The sampling was conducted in accordance with applicable Standard Operating Procedures (SOPs) as referenced in the QAPP. Applicable SOP numbers and titles include:

- HSOP-2: Determination, Identification, and Description of Field Sampling Sites;
- HSOP-4: Chain-of-Custody Procedures, Packing and Shipping Samples;
- HSOP-7: Decontamination of Sampling Equipment;
- HSOP-13: Equipment Rinsate Blank Collection;
- HSOP-29: Labeling and Documentation of Samples;
- HSOP-31: Field Notebooks;
- HS-SOP-6: Procedure for Collecting Surface Soil Samples;
- HS-SOP-57: Soil Sampling Procedure for Test Pits; and
- HS-SOP-72: Split Spoon Sampling.

All Phase II RFI surface soil sample locations were photographed and coordinates recorded using a resource-grade GPS unit. All project data, including laboratory results, logs, notes, photography, and survey information have been reviewed, validated and entered into the project database by Linda L. Tangen, a third party contractor for quality and validated in accordance with the project work plan, and QAPP.

### **1.1.1.1 Test Pits Sites**

Surface soil samples were collected from backhoe test pits at 19 of the 48 sampling sites. At each of these sites, the test pit was excavated to a depth of five feet and soil samples collected as composite samples from the specified depth intervals. The 0- to 6-inch and 6- to 30-inch interval samples were obtained by collecting a subsample at the specified interval from each of the four pit walls, and compositing the four subsamples into a single composite sample. The 30- to 60-inch interval samples were collected from soil piles excavated from this depth and stockpiled separately by the backhoe from the shallower excavated soils.

All soil samples were collected with a decontaminated plastic hand trowel, composited in a clean plastic mixing bowl, and placed in a one-gallon Ziploc bag. Sample bags were labeled with a unique sample number, date and time of collection, and the sample depth. Labeled samples were then placed in a second Ziploc bag for additional protection against sample loss, and stored in coolers while in the field.

Test pit stratigraphy and characteristics were recorded in the project field book and on field forms for documentation of soil conditions, moisture content, evidence of contamination, etc. All test pits were photographed prior to backfill, staked with site-coded wood lath, and location coordinates recorded with a resource-grade GPS. Test pit logs and photographs are presented in *Phase II RFI Report* Appendices, respectively.

All non-disposable sampling equipment, including the plastic trowel and mixing bowl, was decontaminated between surface soil sampling intervals and between test pit locations as follows:

- Loose soil was scraped or brushed from equipment;
- Equipment was then scrubbed with a non-phosphate detergent;
- Equipment was then rinsed with a small amount of tap water; and
- Final rinsing with distilled water.

The backhoe was decontaminated between sampling locations using the pressure washing equipment available at the Facility truck wash.

Field quality control (QC) sampling included collection of duplicate and rinsate blank samples per the project QAPP. Field duplicate samples were collected by compositing soil subsamples from the specified interval in the mixing bowl, then splitting the composited soil into two separate samples. The duplicate samples were assigned unique sample numbers to prevent identification of the samples as duplicates by the analytical laboratory. Field duplicate samples were collected at a frequency of one per twenty field samples. Equipment rinsate blanks were prepared by pouring distilled water over the decontaminated sampling equipment and collecting the water in a 250 ml plastic container, and preserving the samples with nitric acid to pH<2.0. The rinsate blank samples were submitted to the lab for total metals analyses to assess the effectiveness of equipment decontamination procedures and the potential for cross-contamination of soil samples. Rinsate blanks were collected at the frequency of one per day.

All samples were placed in coolers upon collection for storage and transport to the laboratory. Chain-of-custody procedures were followed throughout the project by utilizing standard chain-of-custody forms to transfer samples from the field to the laboratory. Each cooler of transferred samples was accompanied by a cover letter, analytical parameter list, and chain-of-custody documentation.



### **1.1.1.2 Soil Boring/Monitoring Well Sites**

Surface soil samples were also collected at all Phase II drilling locations as directed by the Environmental Protection Agency (EPA). Soil sampling sites included the 20 Phase II soil boring sites and nine monitoring well sites. Sampling intervals at all soil boring/monitoring well locations was identical to that described above for the test pit sites; 0- to 6-inch, 6- to 30-inch and 30- to 60-inch. Soil sampling below the 60-inch depth is discussed below under Subsurface Soil Sampling, Section 1.2.

The Phase II soil borings and monitoring wells were completed either with an air rotary (tubex) rig, a hollow stem auger rig, or a sonic rig. With the exception of the sonic rig borings, all samples were collected from split spoon samplers. Soil samples from the sonic rig borings were obtained directly from the continuous core provided by the sonic rig. Soil samples were obtained directly from the appropriate portion of the split spoon or continuous core, and similar to test pit sampling, placed in appropriately labeled Ziploc bags (double-bagged). Sample containers were labeled with the sample number, soil boring name, sample depth, and date and time of collection. Sample handling, storage and transmittal to the lab were identical to that described above for the test pit samples.

Drilling equipment (augers/casing) was decontaminated between borehole locations and split spoons decontaminated between each sample. Decontamination was completed either with pressure washing equipment available at the Facility truck wash, or with mobile pressure washer equipment provided by the drilling contractor. All decontamination water was containerized for disposal through the Facility water treatment system. All drilling equipment was decontaminated prior to leaving the plant site.

Per the project QAPP, field duplicate samples and equipment rinsate blank samples were collected for QC purposes. Field duplicate samples were collected by compositing the soil from the specified interval in a plastic mixing bowl, then splitting the soil into two separate samples with unique sample numbers. Duplicate samples were collected at a frequency of one duplicate per twenty field samples. Equipment rinsate blanks were collected by pouring DI water over decontaminated sample equipment (i.e. split spoons) and collecting the water in a sample container. Rinsate blanks were collected at the frequency of one per day.

Soil sample descriptions were recorded in the project field book and on borehole logging forms. Besides soil type, information such as moisture content, presence of fill material, soil discoloration or other signs of contamination, and stratigraphic unit (where identifiable) was recorded. After completion, the borehole location was photographed and GPS coordinates recorded. An inventory of all surface soil samples is included in the *Phase II RFI Report*.

### **1.1.2 Surface Soil Sample Analyses**

All surface soil samples were submitted to Energy Laboratories in Helena, Montana for analyses of the full list of metals (plus arsenic and selenium) and pH. The resulting data were reviewed by a Linda L. Tangen, a third party contractor for quality and validated in accordance with the project work plan, and QAPP. The validated data were entered into the project database and distributed to project stakeholders per the *Phase II RFI Data Management Plan* (Hydrometrics, 2010d). The analytical results are included in the appendices of the *Phase II RFI Report* well as in the project database, and are discussed in subsequent sections of this report, as well as the 2010 BERA.

## 1.2 SUBSURFACE SOIL SAMPLING

In addition to the surface soil sampling described above, the *Phase II RFI Report* included extensive subsurface soil sampling. For purposes of this report, subsurface soil samples are defined as those collected from greater than 5-foot depth. Subsurface soil sampling was conducted at the same 20 soil borings and nine monitoring wells previously discussed in Section 1.1. Subsurface soil sampling objectives include: 1) providing information on the distribution of metals in the subsurface soils; and 2) evaluating relationships between subsurface soil concentrations and the arsenic and selenium groundwater plumes. The subsurface soil sampling was also intended to better delineate the soil stratigraphy beneath the site, particularly the occurrence of the low permeability silt/clay layer. Additional boring-specific objectives are discussed in Section 3.1.2 of the *Phase II RFI Work Plan*.

The subsurface soil sampling was conducted in accordance with the *Phase II RFI Work Plan* with a few deviations based on field conditions and/or opportunities to collect additional data or information. Deviations from the work are as follows:

- Soil boring RFI2SB-3 was moved approximately 175 feet south than proposed in the work plan. The location was modified due to limited access to the proposed drilling area (soft soils). It was also decided that relocating the boring to the south edge of Tito Park would provide valuable information on subsurface characteristics and potential contaminant sources near the southern-most or upgradient extent of the current arsenic plume.
- Soil boring RFI2SB-11, located west of the plant site near the stormwater tank, was moved approximately 250 feet west of the original location and completed as a monitoring well (which was not proposed in the work plan). The boring was relocated and completed as a monitoring well (EH-210) to provide complimentary deeper hydrologic information with adjacent shallow monitoring well EH-205.
- Proposed soil boring RFI2SB-19 near former Thornock Lake was not completed due to the presence of overhead power lines, and due to the current availability of soils data from this area.
- Proposed monitoring well EH-140 was not installed due to concerns with drilling through a potential aquitard. Instead, a hydrological assessment specific to the City of East Helena public water supply well EHPWS-3 (Exhibit 1-1), and its susceptibility to contamination from the plant site-derived arsenic and selenium plumes, was completed (Hydrometrics, 2010e). The hydrologic assessment memorandum is included *Phase II RFI Report* appendices.

All other aspects of the subsurface soil sampling program were consistent with the project work plan and QAPP. SOPs referenced in the project QAPP applicable to the subsurface soil sampling include:

- HSOP-4: Chain-of-Custody Procedures, Packing and Shipping Samples;
- HSOP-7: Decontamination of Sampling Equipment;
- HSOP-13: Equipment Rinsate Blank Collection;
- HSOP-29: Labeling and Documentation of Samples;

- HSOP-31: Field Notebooks; and
- HS-SOP-72: Split Spoon Sampling.

### 1.2.1 Subsurface Soil Sampling Protocol

Soil borings and monitoring wells were drilled using air-rotary (tubex), hollow-stem auger, or sonic drilling techniques. Soil samples were collected using a split-spoon sampler with air-rotary and hollow-stem auger drilling techniques as described in the Phase II QAPP and FSAP, while continuous core samples were collected with the sonic drill rig. Split spoon samples were collected every five feet from ground surface to borehole total depth, with additional samples collected in some cases based on changes in lithology.

All drilling activities were supervised by an experienced hydrogeologist or engineer familiar with the project objectives. Subsurface stratigraphy was logged primarily from the 24-inch long split spoon samples collected every five feet, with intervals between split spoons logged from drill cuttings. Soil boring stratigraphy was recorded on field forms, with general notes documented in project field books.

Subsurface soil samples were collected directly from the split spoon or continuous soil core and homogenizing the sample in a plastic mixing bowl. Samples were then transferred to zip-loc plastic bags for storage, with each sample double-bagged to prevent sample loss during storage and transfer to the lab. Because select samples were used for leach and adsorption testing, all air was extruded from the sample containers, to the extent feasible, and samples stored on ice or under refrigeration and in the dark, in an effort to maintain the geochemical integrity of subsurface soil samples. Besides the bagged samples intended for total metals analyses, samples exhibiting signs of petroleum staining and/or odor were also analyzed for petroleum hydrocarbons. Hydrocarbon samples were collected in four ounce, wide-mouth, amber glass jars with minimal headspace. All sample containers were labeled with a unique sample number, along with the date and time of collection and the sample depth. Sample documentation including site name, sample number, date, time, and depth were recorded on field forms and project field books. Sample custody was documented through chain-of-custody procedures in accordance with the *Phase II RFI QAPP* and *FSAP*. Samples were submitted to Energy Laboratories in Helena, Montana and accompanied by a cover letter, analytical parameter list, and chain-of-custody form.

All drilling equipment (augers/casing, split spoons, etc.) was decontaminated between borehole/monitoring well locations using the pressure washing equipment available at the Facility or mobile pressure washer equipment. Split spoon samplers were decontaminated between each sampling interval using the following sequence:

- Brush loose soil from equipment;
- Scrub equipment with a non-phosphate detergent; and
- Final rinse equipment with tap water.

All decontamination water was containerized for disposal to the Facility water treatment system.

Field quality control for the subsurface soil sampling was evaluated through the collection and analysis of field duplicate samples and equipment rinsate blank samples. Field duplicate samples were collected by compositing the soil from the specified interval in a plastic mixing bowl, then splitting the soil into two separate samples with unique sample numbers. Duplicate samples were collected at a frequency of one duplicate per twenty field samples. Equipment rinsate blanks were

collected by pouring DI water over decontaminated sampling equipment (i.e. split spoons), collecting the water in a 250 ml plastic container, and preserving with nitric acid for total metals analyses. Rinsate blanks were collected at the frequency of one per day.

All soil boring and monitoring well locations were recorded for horizontal and vertical control using a resource-grade GPS unit. Select split spoon and core samples were photographed, with project photos included in the *Phase II RFI Report* appendices. Phase II soil boring logs are included in the *Phase II RFI Report* appendices.

### **1.2.2 Subsurface Soil Sample Analyses**

Subsurface soil samples were submitted to Energy Laboratories in Helena, Montana for analyses of total metals and soil pH. Subsurface soil samples with evidence of hydrocarbon contamination (staining and/or odor) were also analyzed for extractable petroleum hydrocarbons (EPH) and volatile petroleum hydrocarbons (VPH). Results of the total metals and EPH and VPH analyses are included in Section 6 of the *Phase II RFI Report* as well as the project database.

#### **1.2.2.1 Total Metals**

A total of 288 subsurface soil samples were collected from the 20 soil borings and nine monitoring wells, and submitted to the lab for analysis of total metals and pH.

#### **1.2.2.2 Hydrocarbon Analyses**

The subsurface soil analyses included testing of eight samples for VPH and EPH based on evidence (staining, odor) of petroleum contamination. These samples were collected at the water table from boring RFI2SB-7 (upgradient of the Speiss/Dross Area), and RFI2SB-16, -17, -20, and -21 (downgradient of this area). These eight samples represent all the samples exhibiting evidence of petroleum impacts.

### **1.3 ADSORPTION/LEACH TESTING**

As noted in Section 3.1.3.2 of the Work Plan, the objectives of the Phase II RFI soil adsorption/leach testing program were:

- Characterize the relative availability to groundwater of soil selenium (and arsenic) in potential source areas;
- Assess adsorption/desorption behavior of selenium and arsenic in different areas of the facility, and the relationship of attenuation mechanisms to the configuration of the groundwater arsenic and selenium plumes; and
- Support further refinement of the site conceptual model, along with updated groundwater transport modeling efforts for selenium and arsenic.

Soil samples for adsorption/leach testing were obtained from soil borings conducted in the Phase II RFI. Locations of the Phase II RFI soil borings (locations RFI2SB-1 through RFI2SB-18, and RFI2SB-20 through RFI2SB-22) and on-site monitoring wells (DH-72 through DH-76) are shown in the *Phase II RFI Report*. Samples were selected for adsorption/leach testing based on the observed total selenium and arsenic results, on the sample locations relative to the current arsenic and selenium groundwater plume configurations observed at the facility, and on the objectives outlined above. Soil samples selected for extraction/adsorption testing of selenium and arsenic,

along with sample information (location and depth), total arsenic and selenium concentrations, and rationale for inclusion of the particular sample in the testing program are summarized in the *Phase II RFI Report*.

Soil adsorption and leach testing consisted of four tests:

- Synthetic Precipitation Leaching Procedure (SPLP; EPA Method 1312);
- Sequential Batch Leach Tests (modified EPA Method 1312);
- Sequential Extraction Tests (USGS, 2007); and
- Batch Adsorption Tests (modified EPA Method 1312 as described in EPA, 1992).

Further description of the test methods and test results are provided in the following sections.

### **Synthetic Precipitation Leaching Procedure (SPLP; EPA Method 1312)**

Previous site characterization efforts (including the Phase I RFI) utilized the SPLP (EPA SW846 Method 1312) test to identify the "readily leachable" mass of contaminants within unsaturated zone soils. As described in EPA SW846, "Method 1312 is designed to determine the mobility of both organic and inorganic analytes present in liquids, soils, and wastes." For solid samples such as soils, the method is summarized as follows:

1. Soil particle size is reduced to less than 9.5 mm (or 0.375 inch), if necessary;
2. For sites west of the Mississippi River, the extraction fluid consists of a 60/40 weight percent mixture of sulfuric and nitric acids added to reagent-grade de-ionized water to yield a pH of 5.0;
3. 50 g of soil is placed in an extraction vessel (e.g., bottle) with 1 liter of extraction fluid (20 to 1 fluid to soil ratio) and agitated (e.g. bottle is rolled continuously) for 16 to 20 hrs; and
4. Following agitation, the extract fluid is separated from the soil by filtration, preserved, and analyzed for pH, dissolved metals and other constituents if desired.

Analysis of unsaturated zone soils (including slag) for leachable concentrations of selenium and arsenic using SPLP provides information on the relationship of total soil concentrations to leachable soil concentrations; on the relationship of total and leachable soil concentrations to concentrations in underlying groundwater; and on the overall potential for site soils to function as ongoing sources of contaminants to groundwater.

### **Sequential Batch Leach Tests (Modified EPA Method 1312)**

As described above, the SPLP test is intended to evaluate the concentration and mass of "readily soluble" constituents in soil or what may be termed the "first-flush" of constituents as soil is initially exposed to a leaching solution such as groundwater or rainfall infiltration. The potential responses of soils to subsequent or repeated exposures to leaching solutions are varied. In some cases, leachate concentrations may be relatively steady and unchanged by further leaching. In other cases, leachate concentrations may decline as the mass of constituents remaining in the soil is depleted. In other cases, leachate concentrations may increase as mineral in the soil are weathered or broken down to release more soluble constituents.

Sequential batch leach tests were used to evaluate the response of the Phase II RFI soils to repeated and prolonged leaching by groundwater. In this testing, a subset of the soil samples collected from

the saturated zone (with one exception) of the Phase II RFI borings were repeatedly (e.g., sequentially) extracted by a modified SPLP bottle roll methodology. To simulate repeated leaching of saturated zone soils by groundwater, the SPLP procedure was modified to use un-impacted groundwater (represented by water from Upper Lake) instead of synthetic precipitation for the extract solution. After each extraction, the extract solution was analyzed for pH and dissolved metals and the soil was re-extracted with fresh Upper Lake water. Samples of saturated zone soil in the area of the Monier Flue were not available, thus an unsaturated zone soil sample was leached instead.

### **Sequential Extraction Tests (USGS, 2007)**

In this testing, both saturated and unsaturated zone soil samples collected from the Phase II RFI borings were sequentially extracted with various reagents intended to selectively liberate arsenic and selenium from different operationally-defined phases in the solid material. The objective of this testing was to evaluate:

- Possible removal mechanisms (adsorption or co-precipitation) for selenium and arsenic from groundwater to aquifer material;
- The potential for remobilization of adsorbed/co-precipitated selenium and arsenic under changing geochemical conditions (i.e., post-corrective measures);
- The distribution of total soil selenium and arsenic in different solid phases, and an associated estimate of what percentage of total soil selenium and arsenic may be considered "available" for loading to groundwater via leaching. Sequential extraction results can be compared with the total mass of selenium and arsenic leached via the sequential batch leach tests described above to assess this availability.

The *Phase II RFI Work Plan* proposed sequential extraction testing using a method outlined in Hydrometrics' standard operating procedure HL-SOP-42, which is based on procedures developed by Gatehouse et al. (1977) for consistency with the Phase I RFI testing procedures. However, since the geochemical occurrence and behavior of selenium is the main focus of the Phase II RFI testing program (as opposed to the emphasis on arsenic in Phase I), an alternative sequential extraction procedure recently developed by the USGS to characterize the geochemical distribution of selenium was employed (Piatak et al., 2006). The phases evaluated with this test procedure are:

1. Water soluble and exchangeable;
2. Carbonates;
3. Organic matter;
4. Amorphous iron/aluminum hydroxides and amorphous and crystalline manganese oxides;
5. Crystalline iron oxides;
6. Sulfide and selenides; and
7. Residual (all arsenic and selenium not in phases 1 through 6).

### **Batch Adsorption Tests (modified EPA Method 1312);**

Adsorption testing of Phase II soils is intended to refine the conceptual site model, in terms of the potential for soil adsorption to control arsenic and selenium migration. Phase II testing and previous work at the facility utilized EPA (2002) procedures and recommendations, modified based on site-specific considerations, to evaluate the adsorption behavior of arsenic and selenium in soils from various portions of the facility.

There are two general approaches to adsorption testing. In the constant soil:solution ratio approach the amount of soil remains constant while the solution concentration is varied. In the variable soil:solution ratio approach the initial solution concentration is constant and soil:solution ratio is varied. EPA considers the variable soil:solution approach to be more conservative and terms isotherms derived from such data as the “environmentally conservative isotherm or ECI”. The advantage of the ECI approach is that the effects of competition from other ions and other processes are implicitly accounted for in the test procedure. The Phase II adsorption tests followed the ECI approach using solutions consisting of site groundwater.

EPA recommends conducting a series of adsorption tests with equilibration (agitation) time durations of 1, 24, 48, and 72 hours in order to document the effect of equilibration time on adsorption and to select a representative test duration. For the Phase II testing, a series of initial adsorption tests were run on four soil samples with groundwater from well EH-11 at the EPA-recommended test durations. In the initial adsorption testing, arsenic adsorption exhibited the typical relationship where adsorption was found to be stronger with increasing test duration up to about 48 to 72 hours, with an overall average change of 5 percent between the 48 and 72-hour test results. EPA recommends selecting a test duration where the percent change in adsorption percentage varies less than 5 percent from the next shorter duration. Therefore, a test duration of 72 hours was selected for further testing. Selenium adsorption was virtually absent in the initial testing and most soils released selenium to the solution.

EPA recommends conducting a series of adsorption tests with soil solution ratios ranging from 1:4 to 1:500 in order select appropriate ratios for further testing. For the Phase II testing, a series of initial adsorption tests were run on four soil samples at the EPA-recommended soil:solution ratios ranging from 1:4 to 1:500. EPA recommends selecting a range of ratios where the amount of analyte adsorbed ranges from about 10 to 30 percent of the amount in solution. It was found in the initial testing that this recommendation was met for arsenic using soil solution ratios from 1:4 to 1:100 and thus this range was used for further testing.

The final Phase II batch adsorption tests were conducted using a modified EPA Method 1312 methodology as described in EPA with the following test parameters:

- 72 hour bottle roll;
- Soil solution ratios of 1:4, 1:10, 1:20, 1:40, 1:60, and 1:100; and
- Solutions consisting of representative groundwater collected from site wells.

### **1.4 MONITORING WELL INSTALLATION**

Nine monitoring wells were installed as part of the Phase II RFI Site Characterization within the Facility, and north/northwest of the Facility as shown in the *Phase II RFI Report*. Subsurface sampling from monitoring well installation is summarized previously in Section 1.2. The monitoring wells were installed to provide detailed information on three dimensional groundwater

flow at the site, further delineate source areas for arsenic and selenium groundwater plumes and delineate the three dimensional plume configurations, and further delineate the top of the silt/clay unit (base of shallow aquifer). Specific objectives of each well and variations from the Work Plan are discussed in Section 1.4.2.

#### **1.4.1 Monitoring Well Installation and Testing**

Monitoring wells were drilled using Air-Rotary (Tubex) and Sonic drilling techniques to penetrate the boulders, cobbles, and gravel typical of the East Helena area. All wells were constructed of 2-inch inside diameter (ID) NFS-approved schedule 40 PVC with flush threaded joint couplings and 0.010-inch factory slotted screen. The borehole annulus was backfilled with silica sand from the well bottom to three feet above the top of screen to provide a filter pack. The remainder of the borehole annulus was backfilled with bentonite chips/pellets to seal the borehole annulus and prevent fluid migration along the outer well casing. All well construction and grouting details were consistent with State of Montana monitoring well construction regulations (ARM 36.21.800). All drilling and monitoring well construction was supervised by a qualified scientist or engineer, with detailed lithologic and construction logs recorded on field forms and a project field book. Monitoring well locations and measuring points (typically top of PVC) was surveyed with a survey grade GPS following well completion.

Following well construction the new monitoring wells were developed to remove fine sediments from the screen interval and improve the hydraulic connection with the aquifer. The procedures for well development consisted of surging the well to bring the fines into the well, and then bailing the well to remove the fines from the well. Lastly the well was pumped with a Grundfos Redi-Flo 2 submersible pump to remove the remaining fines and insure the well is hydraulically connected to the aquifer. A minimum of five well volumes was pumped from each well during development.

Testing of the new monitoring wells consisted of water quality monitoring and aquifer testing. Water quality monitoring was conducted as part of the Post RI/FS Long-Term Monitoring Program, which included measurement of static water levels, field parameters and collection of water quality samples. Water quality samples were submitted to Energy Laboratories in Helena, Montana for analyses of physical parameters, common ions, and trace constituents.

Aquifer tests were conducted using pneumatic slug testing procedures to estimate aquifer transmissivity at the new monitoring wells. The pneumatic slug tests were conducted by depressing the water table by applying pressure to the well through the pneumatic slug apparatus. The well was instrumented with a pressure transducer to measure water levels as the well was pressurized. Once water levels stabilized, the pressure was instantaneously released from the well and the pressure transducer recorded the water level rise. Three slug tests were conducted at each well to ensure reproducible results and provide accurate hydraulic properties.

#### **1.4.2 Monitoring Well Completion**

A total of nine monitoring wells were completed as part of the Phase II RFI Site Characterization. Survey details and well locations are summarized in the *Phase II RI Report*. Monitoring well logs are included in *Phase II RFI Report* appendices. Below is a summary of the Phase II RFI monitoring well completion.



### **Shallow Monitoring Wells**

Three monitoring wells (DH-74, DH-76, and EH-70) were completed in the top portion of the saturated zone. Monitoring wells DH-74 and DH-76 were completed beneath the slag pile to delineate the selenium and arsenic plumes under the slag pile. A bridge of bentonite occurred between the well and drill casing during completion of monitoring well DH-76, causing the well casing to be pulled up approximately 2.5 feet, which resulted in the top of the screen being located just below the sand/bentonite contact. During development and subsequent sampling event, no evidence of bentonite intrusion into the well screen was observed, and the integrity of the well is believed to have been kept intact. Well pair DH-74/DH-75 were installed to evaluate vertical gradients (flow and geochemical) beneath the slag pile. Downgradient monitoring well EH-70 was completed in the upper portion of the shallow aquifer and paired with well EH-125 to evaluate vertical gradients downgradient of the Facility.

### **Intermediate Monitoring Wells**

Monitoring wells DH-73, DH-75, EH-138 and EH-139 were completed in the lower portion of the shallow aquifer and have been identified as intermediate monitoring wells to distinguish them from wells completed in the upper portion of the shallow aquifer. Well DH-75 was completed in the lower portion of the shallow aquifer (136-146) to evaluate water quality in the lower portion of the aquifer beneath the slag pile and as noted above, to evaluate vertical gradients between shallow well DH-74. Well DH-73, located at the southwestern base of the slag pile is paired with well DH-9, was completed from 38 to 48 feet below ground surface (bgs) in tertiary sediments that overlay the silt/clay unit to further delineate the arsenic and selenium plume near the slag pile and provide additional on-site vertical gradient data.

Two wells (EH-138 and EH-139) were drilled north of Lamping Field to delineate the northwest selenium plume. Well EH-138 was completed with 30 feet of screen from 55 to 85 feet, to monitor the approximate same interval of the aquifer that the East Helena PWS #3 well (EHPW-3) is completed in. Well EH-139 was completed with ten feet of screen in sandy gravel material that overlays the base of the aquifer (57 feet bgs). The base of the aquifer was not encountered in well EH-138, but based on the similar stratigraphy within and above the screen interval (sandy gravel and silty sand, respectively) at EH-139 and EH-138, the completion of well EH-138 is believed to be near the base of the aquifer.

### **Deep Monitoring Wells**

Two wells (DH-72 and EH-210) were completed beneath the base of the shallow aquifer (tertiary silt/clay layer). Well EH-210, which is paired with EH-205, was completed in soil boring RFI2SB-11 to provide additional water quality information west of the Facility and provide information on the vertical gradient (geochemistry/flow) between the perched aquifer (recharged by Wilson Ditch) and the deep aquifer west of the Facility. Well DH-72, located downgradient of the Former Acid Plant Area and paired with DH-59, was proposed to be completed as an intermediate well to evaluate on site plumes and vertical gradients in the area. However, soil borings RFI2SB-4, -18, and -7 encountered the base of the aquifer near the total depth of DH-59. Based on the total depths of the soil boring it was determined to complete well DH-72 as a deep well to evaluate the water quality in the deep aquifer and vertical gradients between the two aquifer systems. Special precautions were taken during well drilling and construction to protect the deep aquifer from the

highly contaminated water found at DH-59. Protection from cross contamination was achieved as follows:

- Eight inch casing was drilled to the base of the shallow aquifer, which was a soft moldable clay;
- The eight inch casing was driven 1.5 feet into the clay (27.5-29 feet) to seal off the upper aquifer;
- The seal was tested by blowing out the water in the eight inch casing and letting the well sit for approximately 2 hours to ensure a seal was obtained; and
- The well was then drilled from 27.5 to 50 feet with 6-inch casing.

The seal of the well was validated during well testing, as there was no water level change in DH-59 during groundwater water monitoring or aquifer testing was conducted on DH-72.

### **1.4.3 Testing Results**

The following section summarizes monitoring well testing analyses., Further detail of hydrogeologic conditions and water quality are discussed in the *Phase II RFI Report*.

#### **Slug Tests**

A total of 21 pneumatic slug tests were performed on 7 monitoring wells. Slug test analyses were analyzed using AQTESOLV (v4.50) to calculate aquifer conductivity values based on the Bouwer and Rice Method (Bouwer and Rice, 1976) for damped water level responses and the Springer and Gelhar Method (Springer and Gelhar, 1991) for under-damped responses. The lowest conductivities were found in the deep aquifer, while intermediate wells generally had higher conductivity values than the shallow wells.

#### **Water Quality**

Water quality samples were collected from the Phase II RFI monitoring wells as part of the Post RI/FS Long-Term Monitoring Program conducted in October 2010. Samples were collected for physical parameters, common ions, and trace constituents.

### **1.5 WATER LEVEL MONITORING**

Groundwater and surface water level monitoring was conducted at 48 sites in 2010, under three separate programs: the groundwater/surface water (GW/SW) interaction program, the supplemental groundwater level monitoring program, and the southwest Lamping Field groundwater evaluation program. The GW/SW interaction and southwest Lamping Field programs are included in the *Phase II RFI Site Characterization Work Plan*, and the Supplemental Groundwater Level Monitoring Program is an additional program added as a time critical task. The groundwater level monitoring conducted under the three programs is discussed below.

The water level monitoring programs include a total of 11 surface water sites and 37 groundwater sites. The 37 groundwater sites include 23 pre-existing and 3 newly installed monitoring wells and 11 piezometers installed in March/April 2010 specifically for the groundwater/surface water interaction evaluation. Of the 48 total sites, 23 were instrumented with water level transducers, programmed to record water level and temperature data at four hour intervals. Water levels at the remaining 25 sites were recorded manually using a calibrated water level tape or from staff gages

for surface water sites. All water level monitoring sites were surveyed for horizontal and vertical control.

### **1.5.1 Monitoring Programs**

**Supplemental Groundwater Level Monitoring Program:** As noted above, this task was added as a time-critical task, to obtain additional information on trends in groundwater levels throughout the project area. The program included continuous groundwater level and temperature monitoring with pressure transducers for determination of general water level trends upgradient, within, and downgradient of the Facility and various potential hydrostratigraphic units. A total of seven wells, listed in the *Phase II RFI Report*, were instrumented with pressure transducers on April 1<sup>st</sup> and April 7<sup>th</sup>, 2010 to measure water levels every four hours. In addition, bi-weekly static water level measurements were collected from April through August and monthly measurements from September through November 2010.

**Groundwater/Surface Water Interaction Program:** This program was conducted to provide a detailed evaluation of groundwater/surface water interactions for Prickly Pear Creek adjacent to and north of the Facility. Monitoring was conducted at 11 wells, 11 piezometers, and 13 surface water sites (11 on Prickly Pear Creek, Lower Lake, and Upper Lake). Surface water stage and groundwater levels were monitored to quantify hydraulic gradients between the creek and the groundwater system. Groundwater monitoring was conducted in monitoring wells near Prickly Pear Creek and in shallow piezometers installed at various locations along the stream bank to assess groundwater levels and saturated conditions immediately adjacent to the creek. Two “mini-piezometers” (IP-102A/B and IP-103A/B), that are paired with surface water sites (PPC-102 and PPC-103), were installed/monitored in the active channel adjacent to Lower Lake. The initial mini-piezometers (IP-102A, and IP-103A) were installed in the middle of the creek in late March. At the time of installation, the snow pack was low and high surface water flows were not expected to reach normal levels, however spring snows and rains increased the snow pack, and surface water flows reached near flooding levels. The high surface water flows washed away the IP/PPC-103 and IP/PPC-102 monitoring stations in late May or early June. Replacement monitoring stations (IP/PPC-102B and IP/PPC-103B) were installed on July 22<sup>nd</sup> near the western bank of the creek and re-instrumented with pressure transducers.

Wells APSD-7 and APSD-8, piezometers PZ-102, PZ-103, IP-102A/B, and IP-103A/B, and surface water sites PPC-102, and PPC-103 were instrumented with pressure transducers to collect water level data every four hours. Static water levels were collected at the 33 groundwater and surface water sites on a bi-weekly basis from April through August and monthly measurements from September to December 2<sup>nd</sup> 2010. Lake stage measurements were collected on a daily basis from April 4, 2010 to December 4, 2010.

**Southwest Lamping Field Groundwater Evaluation Program:** In 2008, monitoring wells EH-128 and EH-132 were installed in the southwest corner of lamping field. The wells are located just east of Wilson Ditch and near the base of the tertiary sediment foothills flanking the Helena Valley. Elevated dissolved arsenic concentrations were detected in both wells. The Southwest Lamping Field Groundwater Evaluation was conducted to determine the source of the elevated arsenic concentrations in these wells. The program included groundwater level monitoring in wells in the vicinity, installation and monitoring of piezometers along Wilson Ditch, and synoptic streamflow survey on Wilson Ditch.

Groundwater level monitoring was conducted through the instrumentation of the two wells with pressure transducers on April 1<sup>st</sup>, 2010 to monitor water levels every four hours, and manual static water level measurements as described in the programs above. The program was expanded on June 18, 2010 to include monitoring well EH-208 and a domestic well (no longer in use) at 2840 Winslow Ave, which are located to the west of EH-128 and southwest of EH-132. These well were instrumented with transducers as described above, and incorporated in the static water level monitoring schedule. Additional wells to the southeast (SP-4, EH-205, and EH-210) and to the north (EH-134) were instrumented with transducers to monitor water levels in wells near Wilson Ditch that are upgradient and downgradient of EH-128 and EH-132.

### **1.5.2 Results**

Water levels collected from pressure transducers were downloaded on December 2, 2010. Non-vented transducers were installed in all of the monitoring sites with the exception of DH-3, DH-13, and DH-18, which had transducers with vented cables to automatically correct for barometric changes. The non-vented transducers were corrected for barometric changes recorded in the baro-logger installed in APSD-8. The baro-logger was installed within the well casing, but above the groundwater level to limit large temperature fluctuations, which can cause error in the pressure reading. Following baro-correction, the transducer data were correlated to a single static water level measurement that was collected near the same time a transducer reading was taken and converted to a water level elevation based on each wells measuring point. Transducer readings were then compared to the remaining manual water level measurements to determine the accuracy of the transducers. With the exception of well EH-130, the manual measurements corresponded well with the transducer readings.

The transducer readings at well EH-130 appear to drift from the manual measurements after downloading the data on April 5<sup>th</sup>. The transducer readings at well EH-130 were compared to the manual measurements taken from April 5<sup>th</sup> to December 3rd to determine if the drift in the readings could be corrected. The average drift in the transducer readings was found to be approximately 0.015 feet per day. The data from April 5<sup>th</sup> to December 3rd was corrected by adding 0.015 feet per day for every reading. Following the correction the manual measurements correspond well to the transducer readings. Water level readings at well EH-130 increased significantly on November 28<sup>th</sup> at 11:00 and remained elevated through November 29<sup>th</sup> at 15:00. This increase in water levels appears to be another error in the transducer at well EH-130, and the data for this time period is believed to be anomalous.

Hydrographs were developed from the transducer data and manual static water level measurements. Groundwater hydrographs were compared to each other and surface water bodies in the area (PPC, Lower Lake, Upper Lake, and Wilson Ditch). There were no wells included in the monitoring programs outlined above that exhibited water level trends similar to water levels in Lower Lake. The comparison allowed for grouping wells into six groups based on overall trends. The groupings have been designated as follows:

- Upper Lake Signature – DH-3;
- Prickly Pear Creek Signature – IP-102, IP-103, PZ-102, PZ-103, PZ-33A, PZ-33B, APSD-7, APSD-8, DH-11, and DH-53;
- GW Signature – DH-13, DH-18, EH-60, EH-103, EH-126, EH-130, EH-131, and EH-134;

- PPC/GW Signature – PZ-36A, PZ-36B, PZ-36C, PZ-9A, PZ-9B, DH-7, DH-10A, and EH-54, EH-67, EH-122, and EH-127;
- Wilson Ditch Influence – EH-128, EH-132, EH-205, EH-210, and SP-4; and
- Seaver Park – EH-208, and 2840 Winslow.

Water level trends are discussed in the *Phase II RFI Report*.

### 1.5.3 Temperature Trends

Groundwater and surface water temperature data were collected in wells instrumented with pressure transducers with the exception of well DH-3, DH-13, and DH-18. Temperature trends were graphed with the hydrographs to help determine similarities in hydrostratigraphic units and recharge sources. These hydrographs are presented in the *Phase II RFI Report*.

### 1.5.4 Barometric Efficiency

Barometric Efficiency (BE) is defined as the change in water level (from barometric pressure) divided by the change in barometric pressure (Clark, 1967). Theoretically, barometric efficiency can range from 0-100%, with a completely confined aquifer having 100% BE and unconfined aquifers having a 0% BE. Many aquifers are classified as unconfined or confined, however most aquifers lie somewhere in-between as most aquitards have some potential to transport water or pressure to the underlying aquifer through primary or secondary porosities. Aquifers classified as unconfined may exhibit barometric efficiencies of 0% near the surface, however heterogeneities within an aquifer provide potential for the aquifer to have some degree of confinement. Since it is not always possible to distinguish water level changes that are caused by barometric-pressure from other factors that may influence water levels (e.g. recharge event, local and/or regional pumping), all barometric efficiencies calculations have some associated error (Gonthier, 2007). The difference in barometric efficiency between wells can provide useful data on the degree of confinement of different aquifers or portions of aquifers (Landmeyer, 1996).

Water level data from a number of wells instrumented with transducers exhibited barometric efficiency effects. Wells EH-60, EH-103, EH-126, EH-130, EH-134, EH-210, EH-208, and 2840 Winslow were all analyzed for barometric efficiency. The precision of the transducers instrumented in wells DH-3, DH-13, and DH-18 were not high enough to evaluate barometric effects in these wells. The remaining wells instrumented with transducers were not analyzed as they either showed a direct influence from surface water (IP-102, IP-103, PZ-102, PZ-103, APSD-7, APSD-8, EH-128, and EH-132) or the water level elevation was within the screen interval (EH-205), as changes in barometric pressure will not affect wells that have these characteristics.

A subset of data was used to calculate the barometric efficiency from each of the wells listed above. The selection of each data subset included data that had a relatively constant (non-barometric) long-term water level change. The non-barometric water level change was removed from each subset of data prior to calculating the barometric efficiency.

The Slope Method (Ferris et al., 1962) was used to calculate barometric efficiency. This method uses a plot of the change in water level versus the change in barometric pressure and applying a linear regression to the plotted points. The slope of the line is the estimated barometric efficiency.

## 1.6 GROUNDWATER MONITORING

The 2010 groundwater monitoring at the East Helena Facility was conducted under the Post RI/FS Semi-Annual Monitoring Program, CAMU Monitoring Program, Selenium Plume Front Monitoring Program, 2009 Monitoring Wells-Additional Sampling, and Initial Sampling of Phase II RFI Monitoring Wells. Additional sampling was conducted at wells EH-200 through –202, SP-3 through SP-5, and piezometers WDPZ-2S and –2D. These wells were sampled to further evaluate background concentrations and water quality in the vicinity of Wilson Ditch. The monitoring sites associated with each monitoring program are summarized in the *Phase II RFI Report*. Below is a description of the additional groundwater monitoring programs.

### 1.6.1 Groundwater Monitoring Programs

**Post RI/FS Semi-Annual Monitoring Program:** The semiannual monitoring events were conducted in June (wet season conditions) and October (low water conditions) to monitor contrasting points of the seasonal hydrograph. The June monitoring event included 165 monitoring wells where static water level (SWL) measurements were taken and 116 where water quality monitoring was conducted. Nine monitoring wells installed as part of the Phase II RFI Site Characterization were added to the October monitoring event, which included 180 monitoring wells where SWL measurements were taken and 127 wells where water quality monitoring was conducted. Monitoring was conducted using two teams to complete the monitoring in as short of time as possible (typically 5 days).

The groundwater monitoring well network encompasses the former plant site as well as upgradient and downgradient areas. Plant site wells include all wells within and immediately adjacent to the Facility where plant activities were historically conducted. Off-site wells are located in the City of East Helena, in Lamping Field (directly west of the City of East Helena), and other properties to the north and west of the facility. Monitoring wells designated for water quality sampling consist of a subset of plant site wells and all of the off-site wells, with the exceptions of EH-66 and EH-121.

Water quality samples as part of the Post RI/FS Semi-Annual Monitoring Program were submitted to Energy Laboratories in Helena, Montana for analyses of physical parameters, common ions, and trace constituents (dissolved).

Deviations from the post-RI/FS monitoring plan included the collection of additional water quality samples and SWLs from wells EHMW-3 (June and Oct.) and EHTW-3 (Oct.) and SWL from the Dartman well during the October monitoring event.

**CAMU Quarterly Monitoring:** Groundwater monitoring of CAMU wells was conducted at monitoring wells MW-1 through MW-11 on a quarterly basis in 2010. Four monitoring wells are located around the perimeter of each of the two CAMU cells: the CAMU Phase I cell is bordered by monitoring wells MW-1, MW-2, MW-3, and MW-4, while the CAMU Phase II cell is bordered by monitoring wells MW-5, MW-8, MW-9, and MW-10. Three additional monitoring wells, MW-6, MW-7 and MW-11, are located peripheral to the CAMU cells. The CAMU well monitoring events conducted during the second (June) and fourth (October) quarters of 2010 coincided with the post-RI/FS semiannual long-term monitoring events conducted during those periods. The third quarter monitoring event was conducted in August. Deviations from the 2010 FSAP are as follows:

- The first quarter CAMU monitoring event was not conducted, as transfer of ownership of the Facility was commencing at this time and contracts and sampling plans were not finalized.
- Monitoring well MW-7 had insufficient water to sample during the June monitoring event.

Water quality samples collected as part of the CAMU Quarterly Monitoring Program were submitted to Energy Laboratories in Helena, Montana for analyses of physical parameters, common ions, and trace constituents (dissolved).

**Selenium Plume Front Monitoring:** Groundwater monitoring was conducted at four monitoring wells (EH-126, -129, -130, and -134) to monitor the lateral shift of the selenium plume from spring to fall. Wells EH-126, -129, and -134 are located in the northern portion of lamping field, and well EH-130 is located north of lamping field on Simac property. The wells were monitored on an approximately monthly basis from May 2010 to July 2010.

Water quality samples collected as part of the Selenium Plume Front Monitoring conducted in April, June, and July were submitted to Energy Laboratories in Helena, Montana for analyses of physical parameters, common ions, and dissolved arsenic and selenium. Samples collected as part of the expanded monitoring program were submitted to Energy Laboratories for analyses of parameters shown in the *Phase II RFI Work Plan*. There were no deviations from the Selenium Plume Front Monitoring Program.

**2009 Monitoring Wells-Additional Sampling:** Fifteen monitoring wells that were installed in 2009 were sampled in March 2010 to provide additional water quality data on wells where limited data had been collected. Water quality samples collected as part of the 2009 Monitoring Wells-Additional Sampling were submitted to Energy Laboratories in Helena, Montana for analyses of physical parameters, common ions, and trace constituents (dissolved). There were no deviations from the 2009 Monitoring Wells-Additional Sampling.

### **1.6.2 Sampling Methodology**

Groundwater monitoring was conducted in accordance with the *2010 Post RI/FS Groundwater and Surface Water FSAP* (Hydrometrics, 2010f), and the *QAPP for Environmental Data Collection Activities at the East Helena Facility* (Hydrometrics, 2010b). The collection of groundwater samples from site monitoring wells generally consisted of three steps:

1. Measurement of static water level;
2. Well purging and monitoring for field parameter stabilization; and
3. Water quality sample collection.

**Static Water Level Measurement:** Static water level measurements were collected using an electric water level probe to determine the depth of groundwater below a specified measuring point (typically the top of the PVC well casing). Static water levels were measured prior to collection of samples or removal/introduction of any equipment to the well. During the June and October 2010 semi-annual monitoring events, static water level measurements were collected in one or two days, prior to initiating water quality sampling. This procedure allows for water levels to be measured over a short time period, which provides more accurate data for developing a potentiometric surface

for each semi-annual monitoring event. Measurement of SWLs during the other monitoring events was conducted immediately prior to sampling the well.

**Well Purging, Field Parameter Measurement and Sample Collection:** In general, the groundwater were conducted in a “clean” (i.e., with lower concentrations of constituents of concern), to “dirty” fashion, based on previous data collected at the site to reduce the potential for cross-contamination of water samples. Groundwater monitoring was conducted using modified high flow techniques through the deployment of a 12-volt submersible pump for the shallow wells and wells that had low purge volumes and a 2-inch Grundfos submersible pump for deeper wells and wells with high purge volumes.

Each monitoring well is equipped with dedicated HDPE tubing that is removed from the well following SWL measurement and attached to the submersible pump. The pump and tubing are installed in the well to a depth near the mid screen. Monitoring wells were purged at a flow rate of approximately 0.5 to 4 gallons per minute (gpm) until three to five well volumes are removed from the well. Routine monitoring of field parameters (pH, dissolved oxygen, temperature, specific conductance) were recorded throughout the purging with at least two reading during removal of each of the last two well volumes. Field parameters were measured using a flow-through device to minimize potential effects from atmospheric exposure. Field meters were calibrated daily according to factory instructions, with calibration results recorded on calibration forms. All purge water was containerized and routed to the Facility water treatment system.

Samples for laboratory analysis were collected only after one of the following purge conditions was met:

- A minimum of three well volumes was removed and successive field parameter measurements agree to within the stability criteria given below; or
- At least five well volumes were removed although field parameter stabilization criteria are not yet met; or
- The well was pumped dry and allowed to recover sufficiently such that adequate sample volumes for rinsing equipment and collecting samples can be removed.

Criteria for field parameter stabilization are summarized in Table 1.

**TABLE 1. FIELD PARAMETER STABILIZATION CRITERIA**

Parameter (Units)	Stability Criteria
pH (standard units)	± 0.1 s.u.
Water temperature (°C)	± 0.2 °C
Specific conductance (µmhos/cm)	± 5% (SC ≤ 100 µmhos/cm) ± 3% (SC > 100 µmhos/cm)
Dissolved oxygen (mg/L)	± 0.3 mg/L

NOTE: Stability criteria obtained from USGS *National Field Manual for the Collection of Water Quality Data: Chapter A4, Collection of Water Samples* (September 1999).



Following well purging, final field parameter measurements were collected and recorded, and groundwater quality samples were obtained. Sample bottles were filled directly from a sampling port, prior to the pumped water passing through the flow-through cell. Samples for trace constituents were filtered through a 0.45µm filter prior to preservation, to allow analysis for the dissolved fraction.

Sample containers were rinsed three times with sample water prior to sample collection, then preserved as appropriate for the intended analysis (e.g., nitric acid preservation to pH < 2 for metals analysis), and stored on ice in coolers at approximately 4±2°C during transport (Table 2).

**TABLE 2. SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS**

Parameters	Sample Containers	Preservative
Field Parameters	None	None
Common Constituents	500 mL HDPE	Cool to 4°C
Trace Constituents (dissolved)	250 mL HDPE	Filter dissolved samples (0.45 µm) HNO <sub>3</sub> to pH <2 Cool to 4°C

Groundwater sampling equipment reused between monitoring locations (12-volt sampling pump and short piece of discharge line used to connect to the dedicated well tubing, or Grundfos 2-inch pump system and non-dedicated tubing) was thoroughly decontaminated between sites. Equipment decontamination consisted of the following steps:

- Rinse with five gallons of soapy water (Alconox or other non-phosphate detergent);
- Rinse with five gallons of clean tap water; and
- Final rinse with three gallons of distilled or deionized water.

### **1.6.3 Field Quality Control Samples**

Field QC samples were collected and analyzed as part of the post-RI/FS long-term groundwater and surface water monitoring program and the CAMU groundwater monitoring program in accordance with the QAPP for Environmental Data Collection Activities for the East Helena Facility (Hydrometrics, 2010b). Field QC sample types included field duplicates, rinsate blanks, and DI blanks. Each field QC sample type were collected at a frequency of 1 per day per sampling team.

#### **Field Blanks (Rinsate Blanks and Deionized Water Blanks)**

The effectiveness of the decontamination procedure was evaluated through the periodic collection of equipment rinsate and deionized (DI) water blanks. Collection of rinsate blanks consisted of pumping deionized water through decontaminated sampling equipment (including filtration equipment as appropriate), and collection of the sample in the same manner as described above. DI blanks consist of deionized water placed directly from storage containers into sample containers and preserved.

## **Field Duplicates**

Field duplicate samples are replicate samples from a single sampling location submitted to a laboratory for the same set of analyses. For the purposes of this project, field duplicates were collected by filling two samples containers consecutively from the sampling location. Duplicates were sent to the same laboratory, but were identified with different sample numbers.

All field QC samples were submitted blind to the laboratory (QC samples were be packaged and shipped in such a manner that the laboratory was be aware of the nature of the samples).

## **1.7 STORMWATER RUNOFF SAMPLING**

The majority of the former plant site is currently covered with concrete, asphalt or temporary synthetic liners. As a result, infiltration capacity across the site is relatively low, and stormwater runoff relatively high. The majority of site runoff is diverted to the rodeo grounds storage tank (or other on site storage facilities), and then to the HDS water treatment plant for treatment and disposal under the facility MPDES permit. Based on the extensive cleanup activities conducted over the past few years, namely the demolition of several structures and placement of temporary covers over the former structure footprints, current stormwater characteristics at the site are not well defined. In order to better quantify current stormwater runoff conditions at the Facility, Hydrometrics conducted stormwater sampling in May 2010. Although not part of the Phase II RFI, the stormwater sampling results may prove useful in assessing contaminant sources and assessing corrective measures for the site.

### **1.7.1 Sampling Methodology**

Stormwater sampling occurred during a high intensity rainfall event on May 24, 2010. Runoff samples were collected at the outfalls of all major plant site drainage areas (as defined in the facility SWPPP), and from subdrainage areas within the major drainages. A total of 17 runoff samples were collected from throughout the plant site, with the sample locations corresponding to major stormwater collection points (i.e., sumps), or stormwater conveyances, or in some cases from areas of concentrated overland flow. Sampling included measurement of runoff water pH and conductance (SC) in the field, and estimation (by visual means) of runoff flow at each site. Samples were also collected for laboratory analyses, including one 250-ml plastic bottle, unfiltered/preserved with nitric acid for total recoverable metals analyses, and a 500-ml plastic container, unfiltered/unpreserved for analysis of TSS and pH. All sites were also photographed at the time of sampling. The sampling locations and a photolog of the sampling event are included in the *Phase II RFI Report*.

Of the 17 samples collected, nine were submitted to Energy Laboratories in Helena, Montana for analysis of TSS, pH and total recoverable arsenic, selenium, cadmium, copper, iron, lead and zinc. Eight samples represent main sumps or stormwater collections points, with the remaining samples representing subareas draining to these main sample points. Original plans called for analysis of additional samples pending analytical results from the main collection points, but the stormwater evaluation program was terminated prior to any further analyses.

## **1.8 SURFACE WATER MONITORING**

Post RI/FS surface water monitoring was conducted on July 8, 2010 and November 9, 2010. Surface water monitoring consisted of semiannual collection of water quality samples, stage measurements, and discharge (stream flow) measurements at five sites on Prickly Pear Creek and

water quality samples collection and stage measurements at Lower Lake and Upper Lake (November only). Surface water monitoring locations in 2010 are described in the *Phase II RFI Report*.

Surface water monitoring on Prickly Pear Creek was conducted in a synoptic fashion. Sites were sampled and stream flows measured from downstream to upstream in a single day, to provide information on flow gains and losses and instream parameter loading trends across various stream reaches, while minimizing the possibility of temporal variability.

Water quality samples were submitted to Energy Laboratories in Helena, MT for analyses of physical parameters, common constituents, and a comprehensive suite of trace constituents as listed in Table 2. With the exception of aluminum, trace constituents were analyzed for the total recoverable fraction; aluminum were analyzed for the dissolved fraction.

As noted above, the sampling team inadvertently omitted sampling of Upper Lake during the July monitoring. This was the only deviation from the monitoring plan.

## **1.9 GROUNDWATER/SURFACE WATER INTERACTION STUDY**

The *Phase II RFI Site Characterization Work Plan* (Hydrometrics, 2010) identified the groundwater/surface water interaction between the shallow aquifer and Prickly Pear Creek as being of significance to quantifying groundwater flow and contaminant fate and transport in and around the Facility. Past synoptic streamflow monitoring on Prickly Pear Creek indicated decreased flows (due to seepage) north of the Facility. Streamflow monitoring results adjacent to the Facility were within the level of error associated with streamflow measurements. The evaluation of groundwater/surface water interactions in association with Prickly Pear Creek and the shallow aquifer was designed to better quantify the direction and rate of flow between the creek and groundwater. The objectives of the groundwater/surface water interactions evaluation include:

1. Quantify the direction and rate of flow between Prickly Pear Creek and the groundwater system adjacent to and north of the Facility.
2. Identify areas of groundwater recharge, and potential contaminant transport, to the creek.
3. Evaluate the effect of seepage from the creek on groundwater flow directions and plume migration directions and rates north of the Facility.
4. Provide information on leakage rates from Prickly Pear Creek to the shallow/intermediate aquifer (or vice versa) for use in set up and calibration of the numerical groundwater flow model.

The Phase II RFI groundwater/surface water interactions investigation included detailed synoptic streamflow monitoring along the targeted segment of the creek, detailed surface water/groundwater level monitoring to quantify hydraulic gradients between the creek and the groundwater system, installation of piezometers near the creek bank, and installation of “mini-piezometers” within the active channel above the diversion dam located near Lower Lake. The methods for each component of the investigation are described in the following sections.

### **1.9.1 GW/SW Interaction Investigation Methodologies**

The methodologies used for the steam flow monitoring, groundwater level and surface water stage monitoring, and piezometer and “mini-piezometer” installation were designed to provide detailed

data to quantify the direction and rate of flow from Prickly Pear Creek to groundwater (or vice versa). The groundwater level and surface water stage monitoring, as well as information on stream flow monitoring and installation of piezometers and “mini-piezometers,” are summarized below.

### **1.9.1.1 Synoptic Streamflow Monitoring**

Two synoptic stream flow surveys were conducted on Prickly Pear Creek during baseflow conditions (December 1, 2009) and during high flow conditions (August 4, 2010) to document changes in stream flow through the study area. Stream flow measurements were recorded at 14 locations along Prickly Pear Creek, at 3 diversions from Prickly Pear Creek (1 diversion in December), and at three tributaries (including outfalls) to the creek. Measurements were collected using two monitoring teams to collect the measurements as quickly as possible to provide a point-in-time snapshot of stream flow rates along the stream reach. One monitoring team started at site SG-16 and the other team started at SG-08 and worked upstream following completion of each stream flow measurement. At the end of the day the monitoring teams met back at site SG-08 (SG-10 for August event), where each team measured the flow at SG-08 to calculate the difference in flow over time and compare flows from each team.

Flow measurements were recorded at each site by the area-velocity method using a Marsh-McBirney flow meter and wading rod, with discharge calculated by the USGS midsection/six tenths-depth method. In general, the area velocity method divides the entire stream width into subsections and the stream velocity measured at the midpoint of each subsection and at a depth equivalent to six-tenths of the total subsection depth. The velocity in each subsection was then multiplied by the cross-sectional area to obtain the flow volume through each subsection. The subsection flows were then summed to obtain the total stream flow rate. Stream flow measurements were collected in a stream reach as straight and free of obstructions as possible, to minimize potential measurement error introduced by converging or turbulent flow paths.

During the December 1, 2009 synoptic event, the Marsh McBirney flow meter appeared to malfunction due to cold conditions at gaging sites SG-03 and SG-07. To rectify this malfunction, the monitoring team returned the following day to collect streamflow at SG-03 and SG-07 and one additional site (SG-08) for reference purposes. Estimated December 1<sup>st</sup> flows for sites SG-03 and SG-07 were back calculated by correcting the December 2<sup>nd</sup> flows at each site based on the difference in the December 1<sup>st</sup> and 2<sup>nd</sup> flows at SG-08. The December 1<sup>st</sup> flow from TB-14 (City of East Helena’s Outfall) is based discharge monitoring report (DMR) data for their MPDES permit.

In addition to stream flow measurements, water quality field parameters (ph, specific conductance, temperature, and dissolved oxygen) were recorded at each site to provide additional information on surface water flows and a potential indicator of influxes of groundwater. Field meters were calibrated according to factory instructions, with calibration results recorded on calibration forms. With the exception of pH, field parameter measurements were obtained directly in the stream. Due to the stream having high velocity at many of the monitoring sites, pH was measured in a clean container filled with sample water to limit possible pH measurement errors due to streaming potentials. Results were recorded in the field notebook. All stream flow monitoring sites were photographed during the synoptic event and GPS coordinates recorded with a field grade GPS unit to allow for mapping and locating sites in the future.

### **1.9.1.2 Piezometer Installation**

Nine piezometers and two potentiomanometers, or mini-piezometers, were installed at five locations that are associated with established surface water monitoring stations along Prickly Pear Creek. These instruments were used to assess groundwater levels and saturated conditions immediately adjacent to the creek. Two to three piezometers were installed at each of the five locations. The piezometers will be used in conjunction with the existing monitoring wells to determine the general direction and magnitude of hydraulic gradients between the creek and the shallow aquifer, and evaluate the height of any groundwater mounding beneath the creek. Two potentiomanometers (IP-102 and IP-103) were installed within the active channel of Prickly Pear Creek upgradient of the diversion dam and directly east of Lower Lake and Tito Park to monitor water levels in the underlying groundwater system (and/or hyporehic zone) and compare them to surface water levels.

The piezometers, with the exception of PZ-36C, were installed with a pickup truck-mounted direct-push drill rig to facilitate access to the creek. The piezometers installed by direct-push methods were completed with ¾-inch (ID), schedule 40 flush threaded PVC and five feet of 0.010 inch slot screen. The piezometers were installed perpendicular to the creek with the shallowest piezometer being completed closest to the creek and the deepest furthest from the creek. Piezometer PZ-36C was installed using air-rotary drilling techniques to penetrate the gravel and cobbles that caused refusal using the direct-push drill rig and was completed with 2-inch (ID), schedule 40 flush threaded PVC and five feet of 0.010 inch slot screen.

In late March, two “mini-piezometers” (IP-102A and IP-103A) were installed in the active channel adjacent to Lower Lake at surface water monitoring stations PPC-102 and PPC-103. The piezometers were installed by driving 1-inch schedule 40 flush threaded PVC into the creek approximately 2 feet, with the bottom 0.5 feet being perforated with approximately 25-30 1/8 inch drill holes. Surface water stilling wells were installed with the mini-piezometers to monitor surface water stage with pressure transducers. In late May or early June, the two mini-piezometers and stilling wells were washed away due to unexpected high surface water flows, which caused flooding in this area. Replacement monitoring stations (IP/PPC-102B and IP/PPC-103B) were installed on July 22<sup>nd</sup> near the western bank of the creek. The replacement monitoring stations were made of 1-inch stainless steel sandpoints,

### **1.9.2 Groundwater/Surface Water Level Monitoring**

A comparison of surface water level elevations to groundwater level elevations immediately adjacent to Prickly Pear Creek was used to further assess the interaction of groundwater and Prickly Pear Creek. The water level monitoring protocol for the groundwater and surface water interaction investigation is described in the following sections.

Groundwater and surface water level monitoring was conducted at 11 wells, 11 piezometers, and 13 surface water sites (11 on Prickly Pear Creek, Lower Lake, and Upper Lake). The water level monitoring was conducted to quantify hydraulic vertical gradients between the creek and the groundwater system, to determine the potential for surface water seepage to groundwater or groundwater discharge to surface water. Manual water level monitoring methods used for groundwater and surface water level monitoring was conducted on an approximately monthly basis. Eight monitoring sites (2 surface water and 6 groundwater) located above the diversion dam and east of Lower Lake were instrumented with pressure transducers to provide continuous (4 hour interval) water level monitoring. All manual water level measurements and transducer data were

used to obtain a water level elevation based on the surveyed measuring point of each monitoring station.

### 1.10 SOUTHWEST LAMPING FIELD HYDROLOGIC EVALUATION

Asarco completed two monitoring events in the southwest corner of Lamping Field in 2009. Water samples from the two wells, EH-128 and EH-132, have consistently contained elevated concentrations of dissolved arsenic, ranging from about 0.025 mg/L to 0.040 mg/L in 2009 and 2010. The elevated groundwater arsenic in this area was unexpected given the low arsenic concentrations in wells located between southwest Lamping Field and the main plant site-derived groundwater plume. Subsequent testing of soil samples collected during drilling EH-128/-132 revealed no elevated arsenic concentrations in the local soils. In response to the elevated arsenic in the two wells, an evaluation of potential sources of arsenic in the southwest Lamping Field groundwater was included in the *Phase II RFI*.

The Southwest Lamping Field investigation included synoptic stream gaging and water sampling within Wilson Ditch, and groundwater level monitoring in monitoring wells and piezometers located in close proximity to the ditch to assess potential interactions between the ditch water and underlying groundwater system. Procedures of this investigation are discussed below. This information is intended for use in evaluating overall cleanup and closure requirements for the East Helena Facility during the Corrective Measures phase of the project.

#### 1.10.1 Wilson Ditch Synoptic Stream Gaging and Sampling

Wilson Ditch began flowing on May 17, 2010 and flow was turned off on August 30. As is typical for Wilson Ditch, flow was adjusted frequently during the 2010 irrigation season in response to ditch water demands, although flow was continuous from May 7 to August 30. The effect of the onset and cessation of flow in the ditch is evident in the hydrographs from nearby wells EH-128 and EH-132.

##### 1.10.1.1 Synoptic Stream Gaging

**Table 3. 2010 WILSON DITCH SYNOPTIC STREAM GAGING DATA  
EAST HELENA FACILITY**

<b>SITE ID</b>	<b>LOCATION</b>	<b>6/14/2010 Flow</b>	<b>8/10/2010 Flow</b>
WD-2	At Plant Site Boundary	4.01	3.78
WD-4	Center of Manlove Subdivision	na	3.13
WD-3	Immediately north of Highway 12	3.17	2.97
WD-25	Approximately 600 ft north of Seaver Park	na	3.13
WD-26	2500 feet downstream (north) of WD-25	2.57	0.003*

All flows in cubic feet per second

\*Decrease in flow between WD-25 and WD-26 on 8/10/10 is due to diversion from ditch for flood irrigation. There were no surface inflows or diversions to Wilson Ditch on 6/14/10.

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